



# Tevatron Helical Orbits for HEP

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- Helix/Separator Overview
- Luminosity Lifetimes vs Separator Voltages/Helix Size during HEP



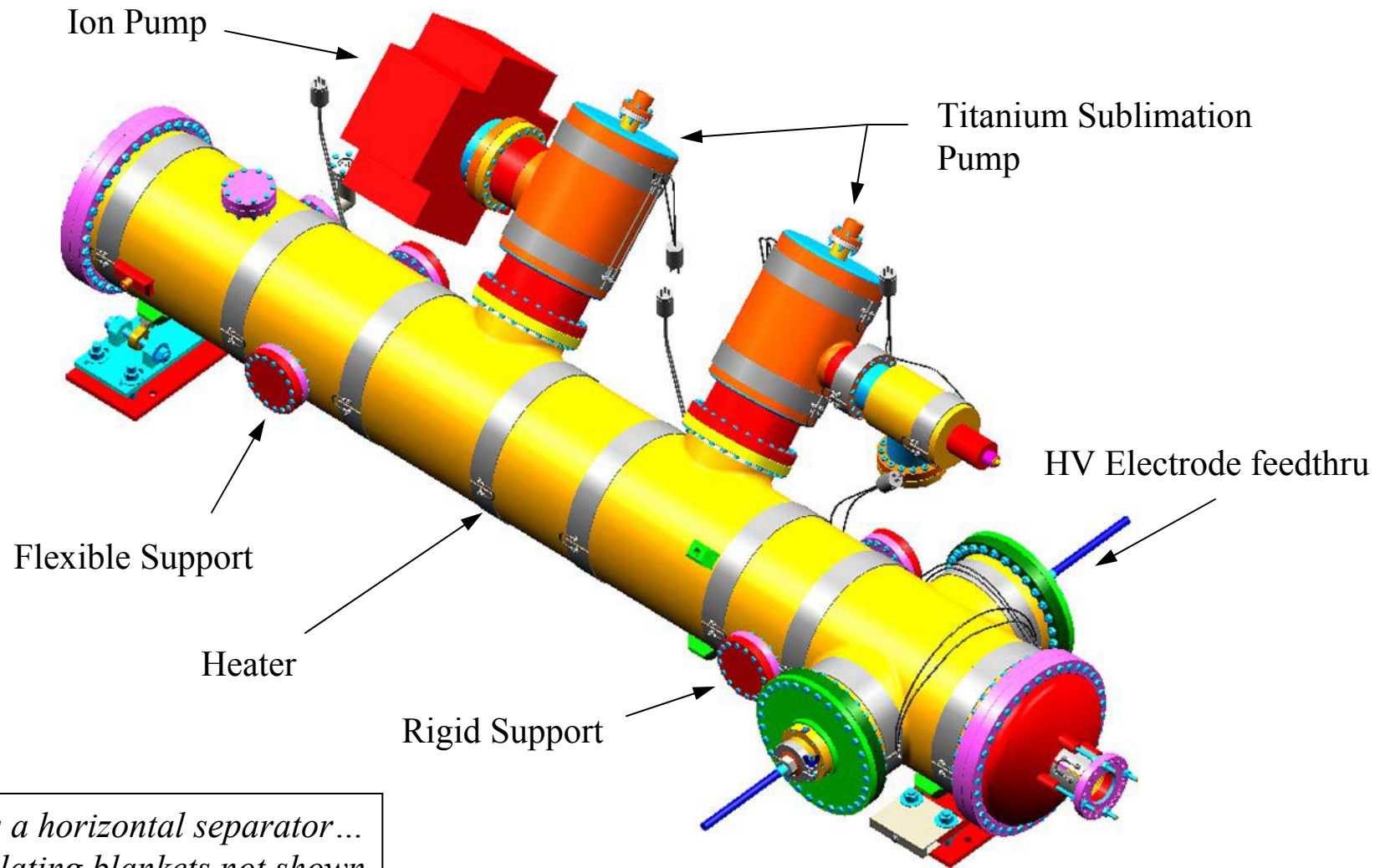
# Helix/Separator Overview

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- Electrostatic separators used to put protons, pbars on different orbits (“helices”)
  - Separators kick protons, pbars in opposite directions
  - Beams spiral around each other (except at CDF, D0  $\Rightarrow$  head-on collisions)
  - 24 separators grouped into 13 stations around the ring (3 on each side of IPs)
- Tevatron has 2 helix schemes
  - “Injection helix”: from injection  $\rightarrow$  middle of low beta squeeze
  - “Collision helix”: middle of low beta squeeze  $\rightarrow$  low beta
    - This is the focus of this presentation.
  - Difference between the two is horizontal position of pbars:
    - Inside at F0 for injection
    - Inside near D0, CDF for HEP (pots for diffractive physics)
  - 5 separator stations used for injection helix, all 13 used for collision helix
    - B11H, B17H, B11V switch polarity between injection and collisions



# Tevatron Electrostatic Separator Components



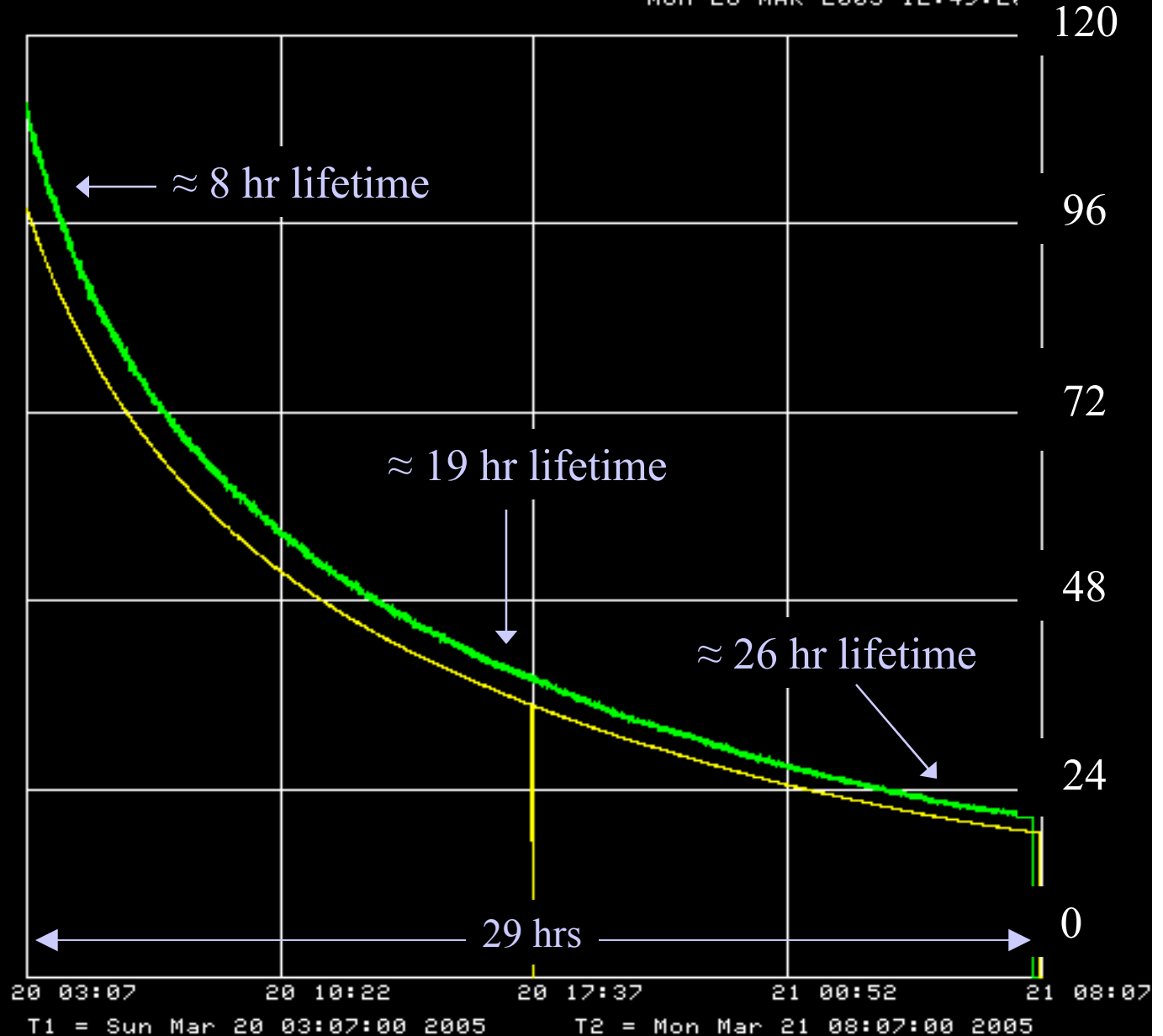
*This is a horizontal separator...  
...insulating blankets not shown*

# Example of Luminosity Evolution – Store 4052 – 100% Helix

Mon 28-MAR-2005 12:49:26

CDF Lumi  
[E30]

D0 Lumi  
[E30]



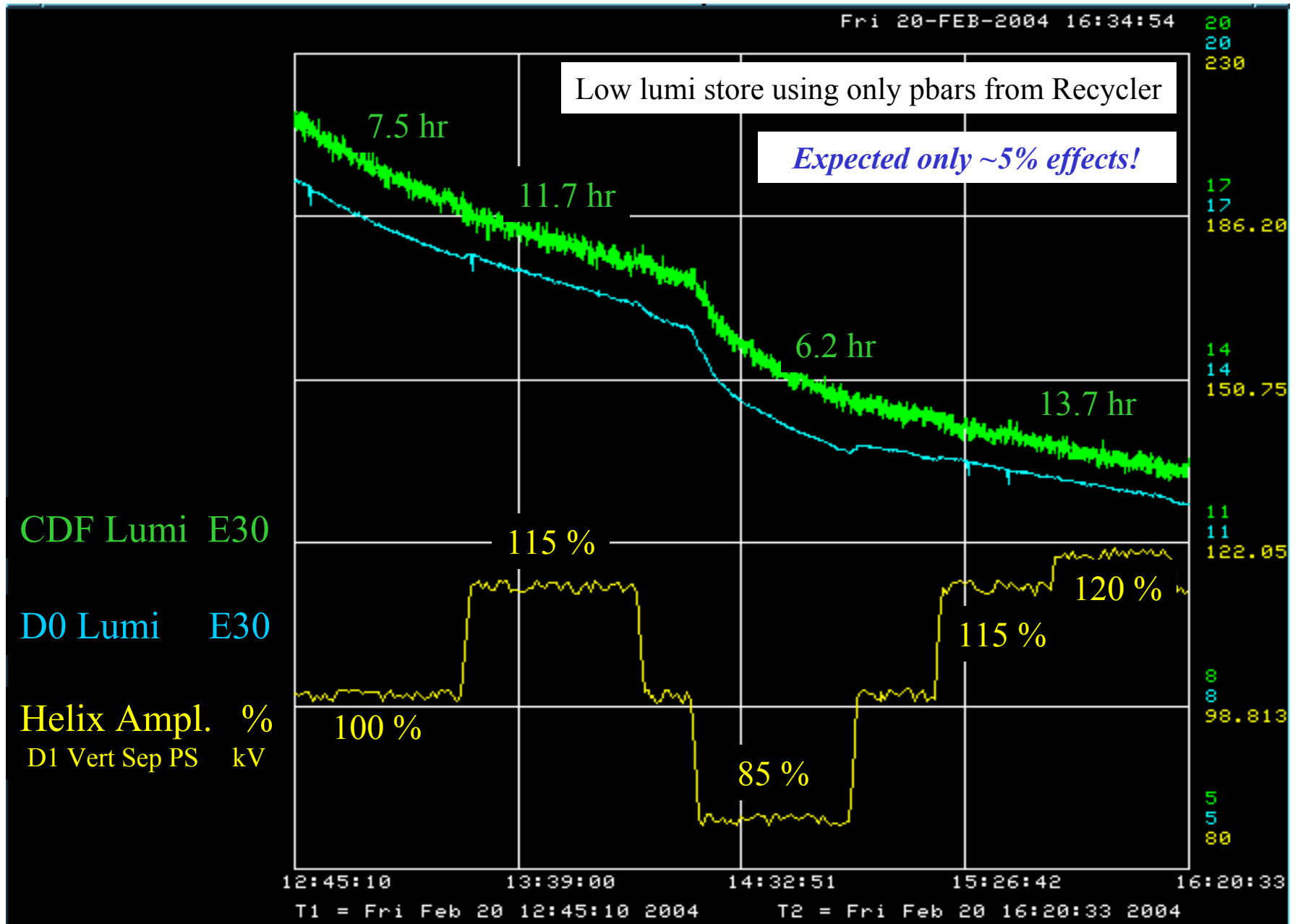


# Higher Separator Voltage Operations / Studies

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- Long range beam-beam effects decrease luminosity lifetime
  - First “parasitic” crossings 57 m from the IPs
  - Increasing separation decreases long range effects more slowly than  $(\text{separation})^{-1}$ 
    - Diminishing benefit for increased separation
- Focus on trying higher separator voltages during HEP
  - Most direct way to increase beam-beam separation
  - Understand benefits of larger separation (lifetime) vs increased risk of sparking
  - Better lifetime  $\Rightarrow$  more integrated luminosity
- During HEP stores, IP separators run at  $\sim 100\text{kV}$ 
  - Running @ 120 kV seems to be a realistic goal
  - 20% more voltage  $\Rightarrow$  20% more separation
  - Can IP separators run @ 120 kV for many hours with acceptable spark rate?
    - 1 spark/month is “acceptable” – 1 spark/week is not
    - A plate-to-plate spark in an IP separator typically causes a quench – beam kicked into collimator
- Technical Division helping with separator R&D in teststand at MP9
  - Trying higher voltage conditioning, measuring spark rates
  - Going to test electropolished stainless steel and Ti electrodes

# Luminosity Lifetime vs Helix Amplitude – Start of Store 3247 (Feb 2004)





# Running Separators Harder (2004)

- Benefit from higher luminosity lifetime seen in study?
    - Did not see such dramatic improvement for regular stores
  - Gather spark rate data for higher voltage operations
    - Separation between protons, pbars  $\propto$  voltages
    - Spark rate increases exponentially with voltage
  - Sparks at 100% helix
    - 6 sparks in  $\approx$  4500 hrs from 11/1/02 – 3/1/04
  - Separator sparks at 115% helix (3)
    - B11 vert (110 kV) – 6 hrs into store 3341
    - B11 horz (105 kV) – 5 secs after reaching voltage in 3446
    - B11 horz (105 kV) – 4 hours into store 3629
  - No sparks at 120% helix
- $\Rightarrow$  No evidence of drastic spark rate increase

Separator	# modules	Power Supply Voltage [kV]		
		100%	115%	120%
		Pre 3/2/04	3/2/04-8/6/04	Post 8/6/04
B11H	2	89.2	105.1	109.2
B17H	4	36.0	44.6	46.3
C49H	1	93.5	103.0	107.0
D11H	2	82.7	96.0	100.0
D48H	1	5.3	58.2	58.7
A49H	1	90.7	103.0	107.2
B11V	1	95.4	110.1	114.6
C17V	4	48.4	57.4	59.6
C49V	2	90.5	103.2	107.6
D11V	1	99.8	115.1	120.0
A17V	1	5.1	29.6	30.7
A49V	2	76.7	86.9	90.7
Approx # HEP store hrs			1900	330



# Running Separators Harder (2005)

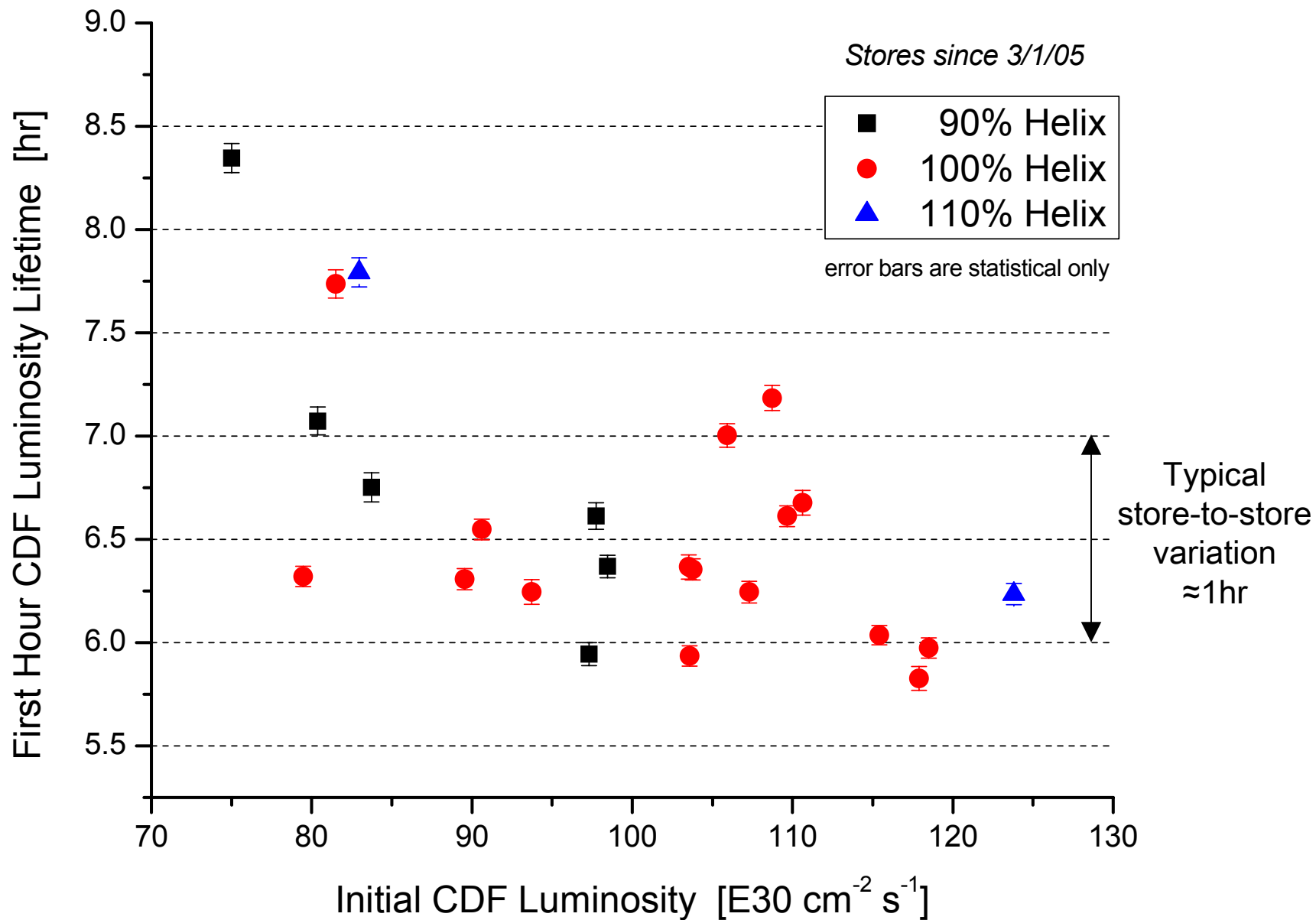
- After Fall 2004 shutdown, wanted to use nearly the same separator voltages for HEP
  - Some differences expected from D17V seps
    - A49V 20 kV higher – spark risk?
      - May need additional conditioning?
  - Highest voltage = 110 kV (“New” 110%)
- Suffered from rash of sparks in Dec 2004
  - Condition + lower seps 10% (“New” 100%)
  - Only 1 spark in 2.5 months @ 100%
- Revisiting lifetime vs helix size studies
  - Running stores at 90%, 100%, 110% helices
  - A49V did spark once at 110% (Store 4053)

Separator	# modules	Power Supply Voltage [kV]		
		120%	New 110%	New 100%
		8/6 - 8/27/04	12/7 - 12/19/04	Post 12/19/04
B11H	2	109.2	109.9	99.5
B17H	4	46.3	47.3	43.4
C49H	1	107.0	110.0	100.1
D11H	2	100.0	108.6	96.2
D48H	1	58.7	65.0	64.8
A49H	1	107.2	110.0	100.1
B11V	1	114.6	110.0	100.1
C17V	4	59.6	56.4	54.4
C49V	2	107.6	102.1	94.9
D11V	1	120.0	110.0	100.1
D17V	2	-----	96.3	92.8
A17V	1	30.7	71.6	40.0
A49V	2	90.7	110.0	100.1

⇒ Need to gather more data before reaching conclusions



## First Hour Luminosity Lifetime vs Initial Luminosity





# Summary

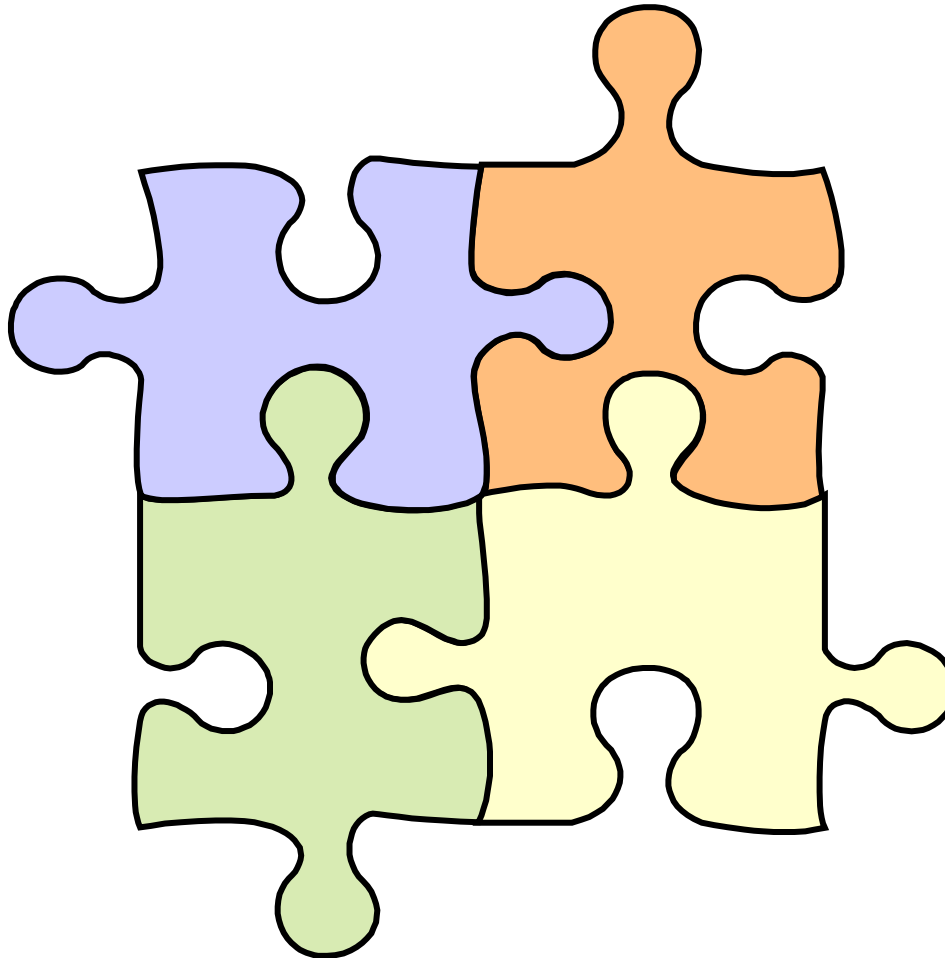
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- Tevatron employs electrostatic separators to separate the proton and pbar beams
  - Make collisions only where want them! (CDF and D0)
- Testing higher separator voltages to increase separation between protons/pbars in HEP
  - Decrease detrimental long-range beam-beam effects to improve lifetime
  - Evaluate lifetime benefits versus higher risk of separator sparks (lost stores)
  - Need to accumulate more statistics!



# Extra Slides

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## Table of Current Separator Stations

Horizontal Locations	# modules	Polarity Switch?	Vertical Locations	# modules	Polarity Switch?
			A17	1	Yes
A49	1	Yes	A49	2	Yes
B11	2	Yes	B11	1	Yes
B17	4	Yes			
			C17	4	Yes
C49	1	Yes	C49	2	Yes
D11	2	Yes	D11	1	Yes
D48	1	Yes	D17	2	Yes

**Items in blue are NEW!**

Total: 24 separator modules + 6 (2 are working spares )  
13 polarity switches + 4 (2 waiting for final checkout)

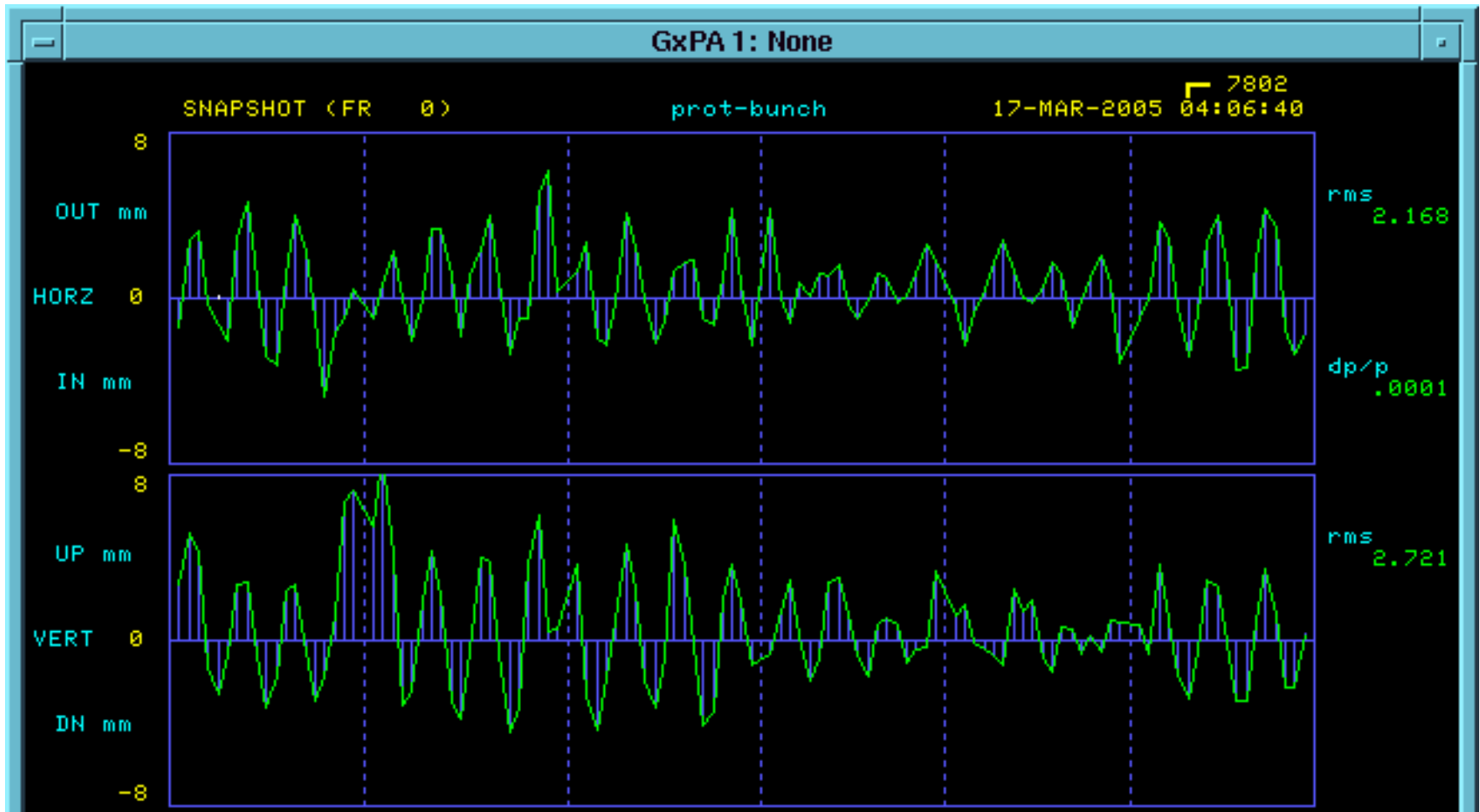


## Brief Description of Separator Modules

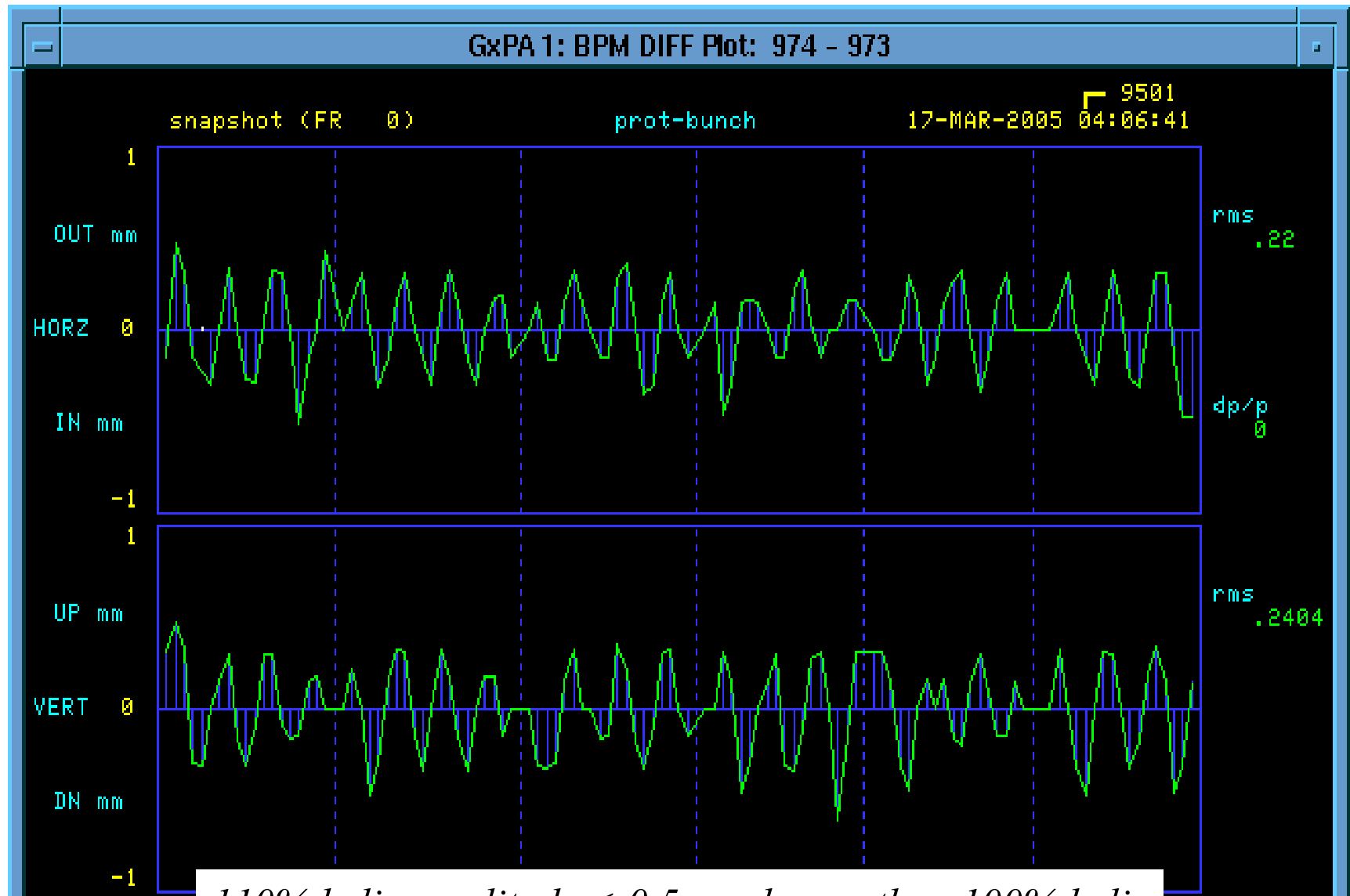
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- 1-4 individual modules in series make up a “separator”
- 257 cm long stainless steel electrodes
  - 297 cm total “slot length” (space needed in tunnel)
- 5 cm gap between electrodes
- Bipolar operation
- Initially conditioned at 150 kV, both polarities, spark rate < 1 per day
- Can bake at 150-200°C in situ
- Attached 220 L/s ion pump, pair of Ti sublimation pumps
- Power supply max voltage is 180 kV
- Usually condition at 130 kV in tunnel (150 kV max)

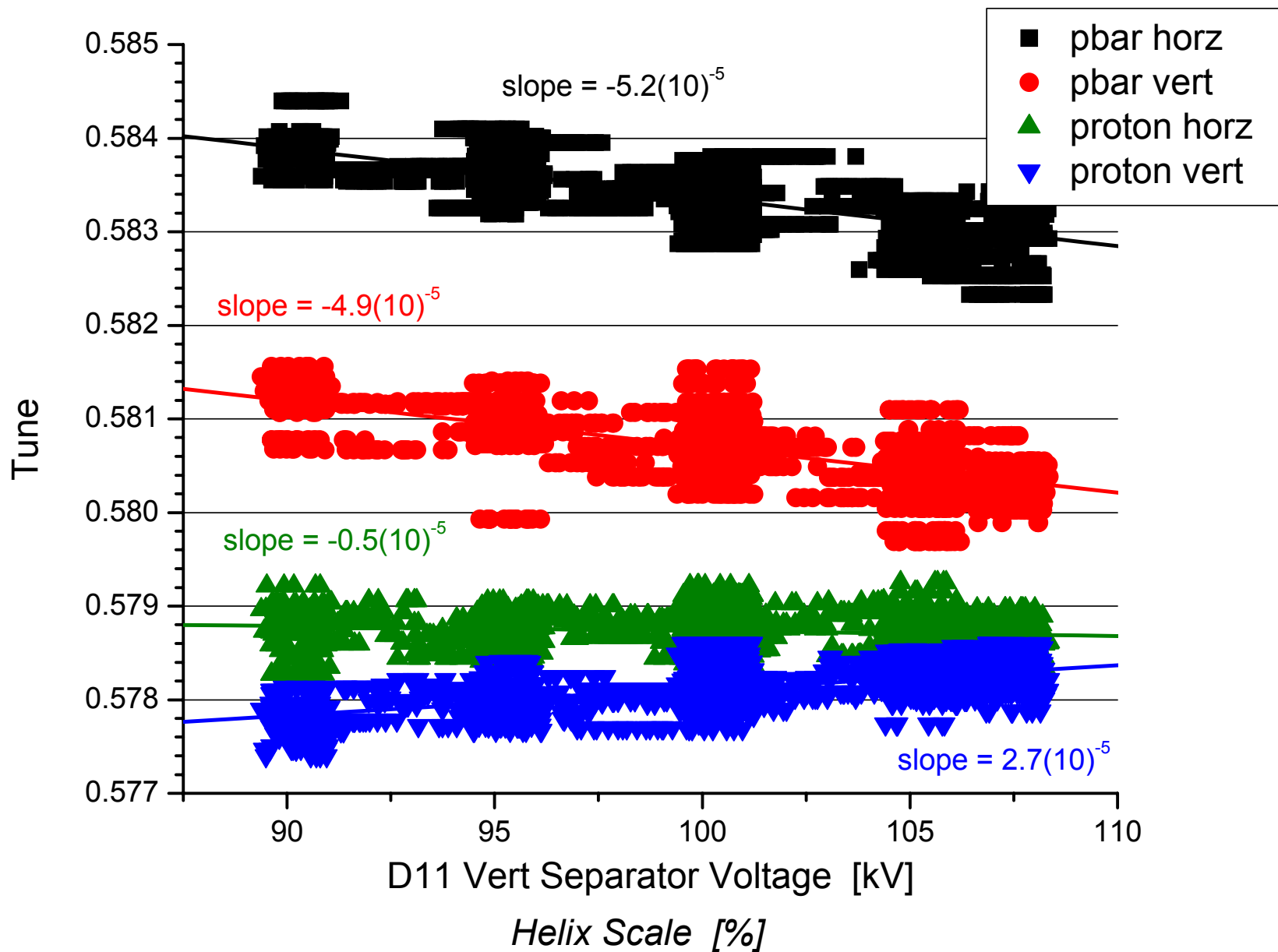
# Orbit Snapshot of 100% Helix (Store 4046)



# Orbit Differences 110%-100% Collision Helix

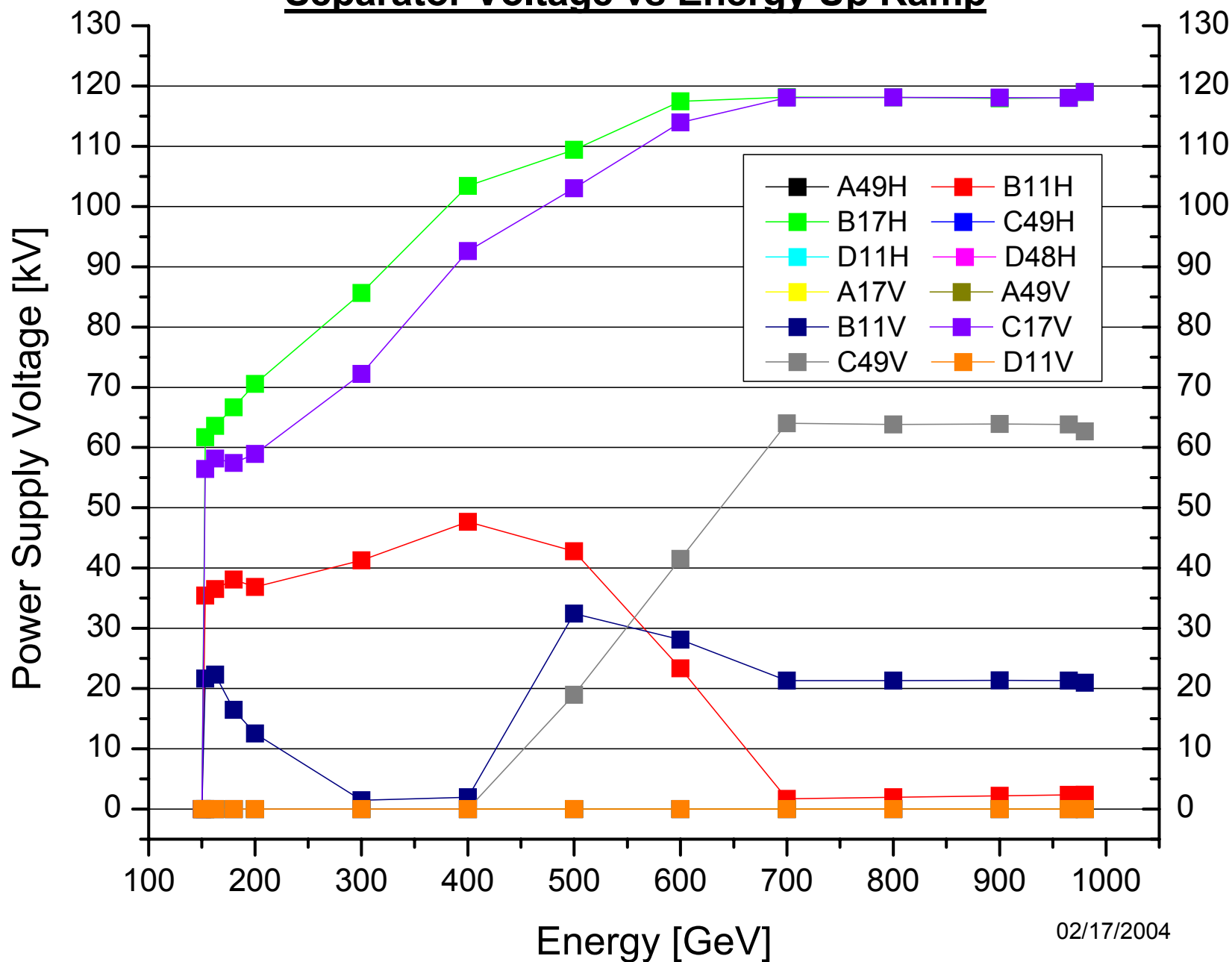


# Tune vs Helix Size (End of Store 4043)



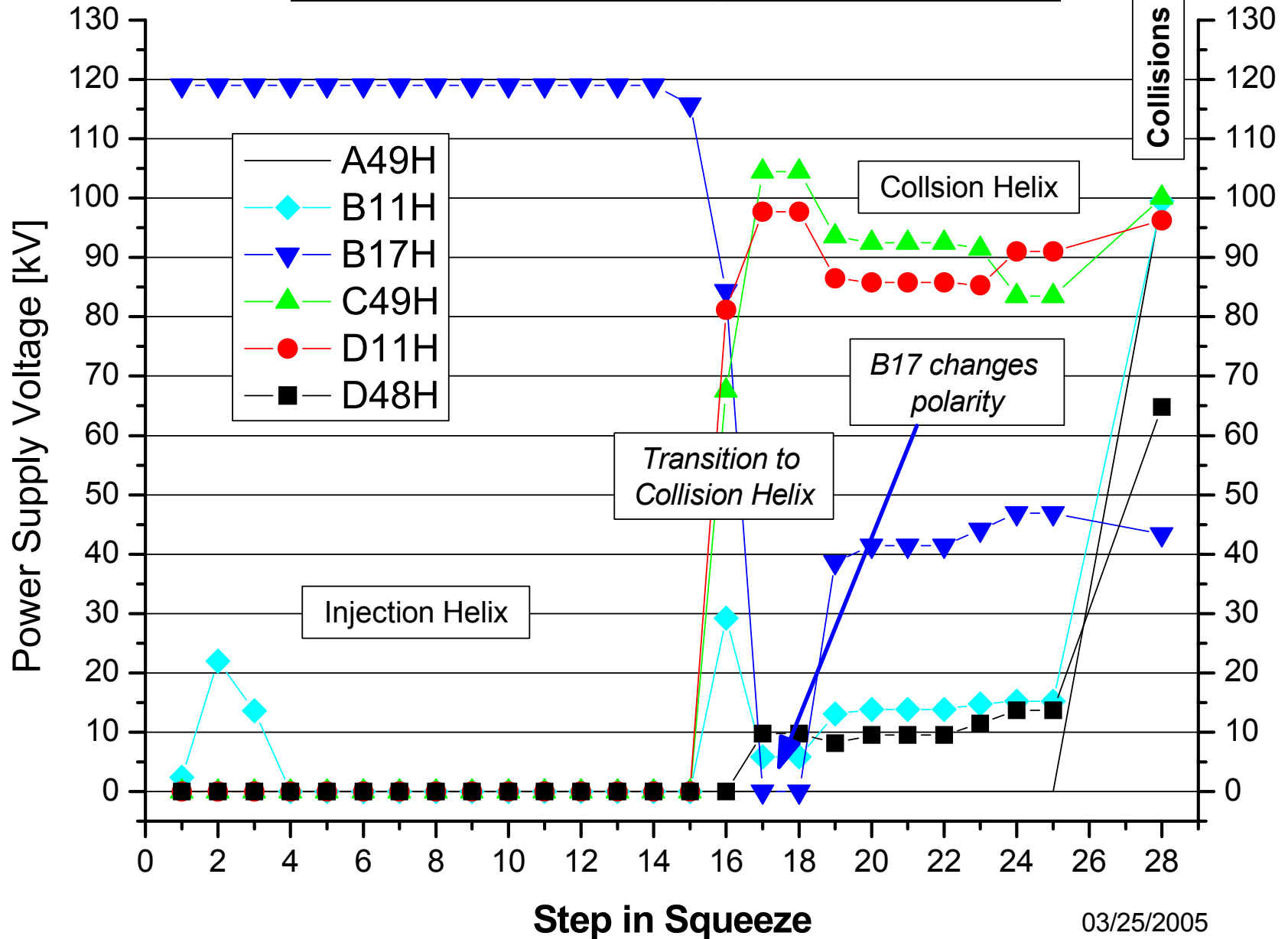


## Separator Voltage vs Energy Up Ramp

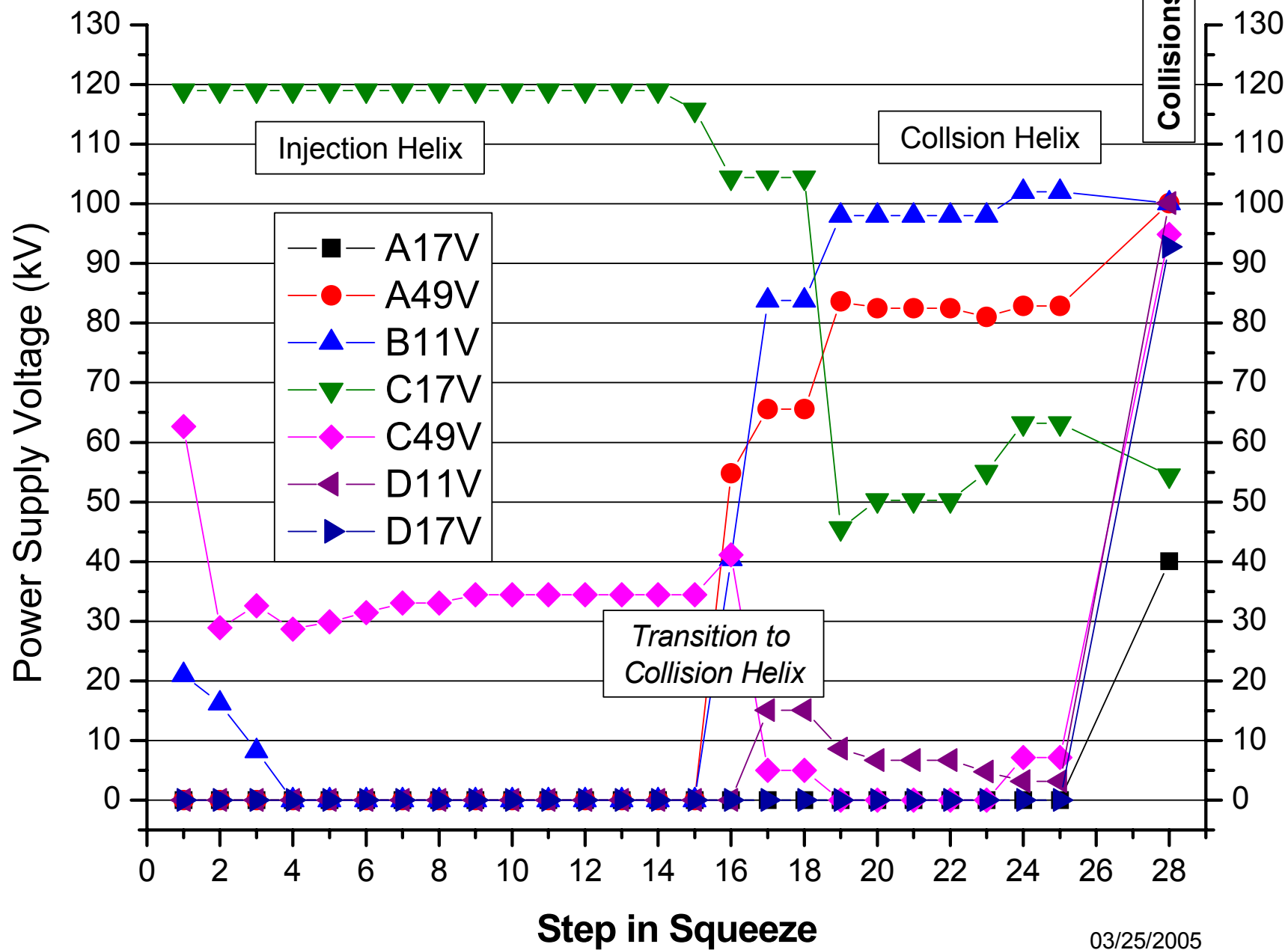


02/17/2004

## Horizontal Separator Voltage vs Step in Squeeze



# Vertical Separator Voltage vs Step in Squeeze



03/25/2005